than in the Pacific ocean. The recent date and the rapid rate of subsidence appear to be of greater importance than its amount in the case of the Great Chagos bank, where the submergence does not seem great enough to drown the reef-building corals. Here the muddy central area is 40 or 50 fathoms deep; it is bordered by an irregular sandy bank from one to 5 miles or more in breadth and from 15 to 20 fathoms in depth, on the outer margin of which rises a rim about a mile in width, and only 5 or 10 fathoms in depth; singularly enough, there is little living coral on the outer rim, though knobs of growing coral rise from the central depression. The diameters of the whole mass range from 50 to 75 miles: its form suggests that a prolonged stationary period, during which a broad atoll-reef was developed, was followed by a subsidence of about 10 fathoms, after which a shorter stationary period permitted the up-growth of a narrower reef; then a rapid and presumably recent subsidence of 5 or more fathoms ensued, since which no effective reef growth has taken place, possibly because, according to Daly's suggestion, the submerged corals were smothered by wave- and current-shifted sediments.

Unfortunately no archipelagoes comparable to those of the Australasian region are present in the Indian ocean to give evidence in the case, but it may be noted that a few high islands which occur in association with the Indian ocean banks—chiefly the granitic islands in the area of the great Seychelles bank—have narrow and unconformable fringing reefs on their deeply eroded and well embayed shores; thus they repeat in a small way the more abundant and therefore more compulsory evidence that is provided by the charts of the Philippines. Further details on these topics are given in an article on "Submarine Banks and the Coral Reef Problem," now in course of publication in the *Journal of Geology*, and in an article on the "Subsidence of Reef-encircled Islands," soon to appear in the *Bulletin of the Geological Society of America*.

DILATION OF THE GREAT ARTERIES DISTAL TO PARTIALLY OCCLUDING BANDS

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The incentive to the work was primarily the desire to cure aneurysms of the abdominal aorta and common iliac arteries.

The method usually employed for the cure of aneurysm is the simplest, viz., the ligation of the affected artery proximal and as close as feasible to the aneurysm. The aorta has been ligated 25 or more times in man, and always with fatal result. Death has been due to hemorrhage or overtaxed heart. Neither gangrene nor paraphlegia has ever resulted from ligation of the aorta

in man. We found, in dogs, as was to have been expected, that fine, completely occluding, ligatures (sizes C or E sewing silk) applied to the thoracic aorta just below the arch would cut through in about two days, and invariably with promptly fatal hemorrhage; whereas coarse ligatures usually made their way through the aorta wall very slowly and without leakage of blood. A connective tissue diaphragm often forms in the wake of these broader threads and the lumen of the vessel may be more or less completely reëstablished.

It occurred to me after much experimentation that occlusion of the aorta to a degree not sufficient fatally to overburden the human heart might effect the cure of an aortic aneurysm. Knotted ligatures we found to be unsuitable, for a desired degree of constriction or obliteration could not be accurately obtained nor could the crushing of the arterial wall be invariably avoided. Tapes of various materials were tested—of cotton, of chromicized intestinal submucosa, of elastic tissue obtained from the aorta, of aponeurotic white fibrous tissue. These were applied in spiral or cuff form. Best suited to the purpose were bands of metal, of aluminum, accurately rolled in cylindrical form by a little instrument of this kind (exhibit). In the use of these metal bands it was impossible to crush the arterial wall, and the desired amount of obturation could be obtained with precision, and also maintained.

The infolded and snugly opposed intimal surfaces under the compressing band have in no instance adhered to each other, and for the reason that the pressure necessary to produce even a very slight reduction in the lumen of the vessel has, in my experience, invariably caused atrophy of its wall. When the occlusion is complete the necrotic arterial wall included in the metal band becomes replaced by a solid cylindrical cord of fibrous tissue, the substitution taking place from the ends.

An interesting incidental observation which we have made in the course of our experiments with the metal band is this; that a dilation of the artery occurs just below a band when the degree of constriction is of the proper amount. This observation apparently explains in a measure the occurrence of aneurysms of the subclavian artery distal to a cervical rib. Analyzing 525 clinical cases of cervical rib we found 106 in which the subclavian artery had been compressed, and that in 21 of these, aneurysm or dilation of this vessel distal to the site of constriction had been noted.

As to the cause of these aneurysms, five of which have come to the knowledge of the collators, there has been varied conjecture. Commentators are, however, agreed that the occurrence of the dilation would have been less incomprehensible to them had it manifested itself on the proximal instead of the distal side of the compression. Attempts have been made to explain the phenomenon, and the following suggestions offered as to its possible cause:

(1) Weakening of the wall of the subclavian artery from erosion by the rib.

(2) Variable or intermittent pulse pressure occasioned by the normal excursions of the arm.

(3) Vasomotor and vasa vasorum disturbances leading to modified nutritional activities in the wall of the artery.

In casting about for an explanation of these aneurysms there constantly obtruded itself the picture of the dilated arterial trunks which, I find from the study of about 400 cases, has occasionally been noted on the cardiac side of arterio-venous fistulae. In our own clinical and experimental cases, dilation of the artery proximal to the fistula has occurred invariably. For this remarkable manifestation, likewise, no satisfactory cause has been assigned. There might, I thought, be a common cause for both—for the dilation of the subclavian artery distal to the cervical rib, and for the dilation, central to the arterio-venous fistula, of the artery concerned in its formation. Hence, for a number of years, in the course of various experiments in partial occlusion of the arteries, I had somewhat in view the possibility of the production, beyond the point of constriction, of a dilation of the artery, analogous to the dilations which have been observed in cases of cervical rib.

Four years ago when after many trials I had altogether despaired of having the hope realized, I was startled, on examining the abdomen of a dog whose aorta had been constricted for about six months to see that each of the branches of trifurcation had become dilated almost to the size of the main aortic trunk.

With this observation as incentive, Dr. Mont Reid and I, the following winter, constricted the abdominal aorta just above its trifurcation, in many dogs and at intervals explored and reexplored the abdominal cavities, but with negative result. Finally, on investigating the abdomen of the last dog we found the hoped-for dilation. The degree of obturation of the aorta was accurately determined on sacrificing the animal, and the following year the experiments were more advantageously repeated because of the data obtained from this case. Now, that we have apparently determined the relative amount of constriction required to give the most pronounced results we are able in almost every instance to produce the dilation.

As regards the cause of the dilation produced experimentally we may I think, conclude that it is not to be found in any of the three factors which have been proposed as responsible for the dilation observed in cases of cervical rib, viz., (1) vasomotor paralysis, (2) trauma and (3) variable blood pressure.

Ad. 1. *Vasomotor Paralysis.* (a) The vasomotor nerves and the vasa vasorum are destroyed by the moderately constricting and totally occluding bands quite as surely as by those which, occluding almost totally, have produced the greatest amount of dilation. (b) Only a portion of the circumference of the subclavian artery is exposed to the pressure of the cervical rib and the scalenus anticus muscle and hence only a fraction of the vasomotor nerves or vasa vasorum could be pressed upon.

Ad. 2. *Trauma.* (a) The dilation is usually fusiform and distal to the rib. (b) Trauma is excluded as a factor in the experimental dilations.

Ad. 3. *Variable Blood Pressure.* (a) Patients suffering from the pressure-

pain of cervical rib rarely make wide excursion movements of the arm. (b) The degree of occlusion is constant in the experimentally constricted vessel.

When an arterial trunk is ligated it becomes occluded to the first proximal and first distal branches and ultimately reduced to a fibrous strand.

From observations which we have made on man and dogs I am quite sure that there may be a remarkable fall in blood pressure in what I have termed 'the dead arterial pocket,' while there is still little if any sign of diminution in the caliber of this portion of the vessel. For example, the right common carotid was ligated by the writer in a case of aneurysm of the external carotid. About 3 months later, in the course of an operation for the excision of the uncured aneurysm, the internal carotid, dead-pocketed between the circle of Willis and the carotid ventricle, was freely exposed for a considerable distance. It had lost its cylindrical form, being flat and tape-like, and, although evidently possessing a considerable lumen, seemed to be empty. When incised, a few drops of blood oozed without pulse from the little cut. The artery was then resected. Its wall was thickened on one side but the lumen was still perhaps three times that of a radial artery. Similar observations I have made twice on the external iliac of the dog after occlusion of this vessel at its origin from the aorta. In the dead pocket between the aorta and the origin of the circumflex iliac and common trunk of the epigastric and obturator arteries the blood pressure must have been almost nil, because from a little slit in the apparently normal arterial wall of the relatively empty external iliac artery the blood escaped very slowly in a tiny, almost pulseless jet about 1 cm. high; whereas, from the femoral artery, below the profunda, the blood spurted normally from a similar knife-prick.

Hence in an artery doomed to obliteration, it would seem that the blood pressure may be lowered before the occlusion process sets in—the lowered pressure being, perhaps, the immediate factor leading to the obliteration.

Can these observations have any bearing upon the explanation of the dilation of the aorta above its trifurcation and of its triad branches in the dog after partial occlusion; of the dilation of the carotid in the human subject which I have observed in one case after partial occlusion of the innominate combined with ligature of the first and third portions of the right subclavian; and of the aneurysm of the third portion of the subclavian in cases of cervical rib?

In 1906 Dr. Richardson and I made the observation that after partial occlusion of the thoracic aorta the maximum pressure may be permanently lowered and the minimum pressure permanently increased distal to the constricting band; and in recent experiments Dr. Reid and I have observed that after constriction of the lower abdominal aorta the diastolic pressure may be so increased and the systolic pressure so lowered as to reduce the pulse pressure by nearly one half. The blood stream in this case, passing with greater velocity and less pressure through the band prevents the obliteration of the artery to the nearest branch, the pocket being not a dead one as it is in the case of

total obliteration. The blood in this pocket beyond the constriction streams, presumably, in whirlpools, somewhat as in the vein and, also, as in the artery in arterio-venous fistula; the thrill, not palpable at first if the occlusion has been nearly complete, later may be perceived with the finger; and the bruit, always audible with the stethoscope, becomes louder as the peripheral arterial resistance increases.

To these factors, then—to the abnormal play of the blood in the relatively, as distinguished from the absolutely dead pocket and to the absence of normal pulse pressure, essential probably to the maintenance of the integrity of the arterial wall, we may have to look for the solution of our problem.

We have completely occluded the aorta just above the trifurcation only in dogs. Usually there has been no distal dilation, and in a previous paper I made the statement that dilation had not been observed below a totally occluding band. Since then, however, a slight degree of dilation, distal to the completely obturated vessel, has taken place in three instances. A dilation of this ventricle-like portion of the aorta between the band and the trifurcation might be expected even in case of complete occlusion, for the anastomosis is very free in this situation and the dead pocket is usually, and perhaps always too short to become obliterated. Lumbar branches may be given off just below, as they are just above the band.

In two instances I have made the following observation in testing, during the life of the animal, for the patency of the aorta under the band. Pressure with the finger immediately above the band shut off the pulse in what we term the ventricle; whereas, pressure with the back of the scalpel-blade, made as close to the band as possible, did not. In these cases there was a patent lumbar artery so close to the proximal edge of the band that pressure by the finger obliterated it, whereas, the knife blade which could be brought to bear on the aortic wall between this little artery and the upper edge of the band did not interrupt the flow in this important asastomotic branch. The contribution of this little artery to the anastomotic bloodstream was sufficient to convert an impalpable into a palpable pulse. A palpable pulse in the ventricle below the band is so invariable, whether the aorta has been completely occluded or not, that the patency of the artery under the band cannot be definitely determined during the life of the animal unless temporary occlusion of it between the band and the nearest lumbar artery obliterates or decidedly influences the pulse in the ventricle. If pressure above the band does not affect the pulse just below it we may conclude that obturation is complete.

Fortunately it occurred to me a few days ago to restudy, with reference to the possibility of finding depicted a dilation of an artery below a ligature, the sketches of surgeons who in bygone years had experimentally ligated the blood-vessels of animals. I was delightfully surprised to find, in the beautifully illustrated volume of Luigi Porta[1] published in 1845 two drawings which portrayed a pronounced dilation of the aorta and its ventricle immediately below

the site of ligation. The ligatures in the two dogs had been applied eight and fifteen months before the death of the animals. There is a great bundle of dilated vessels—the vasa vasis—bridging the gap between the retracted ends of the divided aorta.

Thus three-quarters of a century ago this great, perhaps the greatest surgeon of Italy, furnished irrefutable proof of a remarkable phenomenon which must eventually have interest for the physiologist, the pathologist and the surgeon. Luigi Porta describes the drawing but makes no further comment upon the dilation.

Before the introduction of antiseptic surgery by Lister, thrombosis quite invariably followed ligation of an artery, and it was to the organization of the thrombus that the surgeon looked for the prevention of secondary hemorrhage and for the preservation of the life of the patient. If thrombi formed in these two cases of Porta they must have been eventually absorbed, for the distribution of the dilated vasa vasis proves that the aortic free ends were patulous, and we have further proof of this in the dilation of the aortic ventricle just below the site of the ligation.

In the course of my experiments in partial occlusion of the arteries I have often studied the illustrations, carefully I thought, in Luigi Porta's work, but not until I scanned them with the particular object in view did I discover the dilations so strikingly manifest. I wonder if anyone has ever commented upon or been interested in these two observations of Porta.

In the human subject I have in one instance observed a remarkable dilation of an artery distal to a partially occluding band. In this case an aluminum band was applied to the innominate artery for the cure of a subclavian aneurysm. A few weeks later, the aneurysm being uninfluenced by this procedure, the subclavian artery was ligated both proximal and distal to the sac, and a cure effected. Three years later a quite cylindrical dilation of the right common carotid was observed; and now, twelve years after the application of the band, the common carotid artery is strikingly dilated throughout its entire length. The band on the innominate can be palpated; the blood is coursing through it, and distal to the band is a distinct bruit (exhibit).

Summary.—1. A partially occluded artery (abdominal aorta, innominate, carotid, subclavian) may dilate distal to the site of constriction.

2. The dilation is circumscribed and has been greatest when the lumen of the artery (the aorta) was reduced to one-third or perhaps one-fourth of its original size.

3. When the obturation has been slight in amount dilation has not been observed; of 7 cases of complete obstruction there was a very moderate degree of dilation in 3, and none in 4.

4. Complete or partial occlusion of the thoracic aorta may be followed by dilation central to the point of constriction.

5. Dilation or aneurysm of the subclavian artery has been observed twenty-seven or more times in cases of cervical rib.

6. The dilation of the subclavian is circumscribed, is distal to the point of constriction, and strikingly resembles the dilation which we have produced experimentally.

7. The dilation of the artery proximal to an arterio-venous fistula and distal to a partially occluding band may prove to be referable to the same cause.

8. When the lumen of the aorta is considerably constricted the systolic pressure may be permanently so lowered and the diastolic pressure so increased that the pulse pressure may be diminished by one-half.

9. The experimentally produced dilations and the aneurysms of the subclavian artery in cases of cervical rib are probably not due to vasomotor paralysis, trauma, or sudden variations in blood pressure.

10. The abnormal, whirlpool-like play of the blood in the relatively dead pocket just below the site of the constriction, and the lowered pulse pressure may be the chief factors concerned in the production of the dilation.

11. Bands, rolled ever so tightly, do not rupture the intima.

12. Intimal surfaces, brought, however gently, in contact by bands or ligatures do not, in our experience, unite by first intention, for the force necessary to occlude the artery is sufficient to cause necrosis of the arterial wall.

13. The death of the arterial wall having been brought about by the pressure of the band, a gradual substitution of the necrotic tissue takes place, the new vessels penetrating it from both ends. It is, I believe, in this manner that an artery becomes occluded, and it is thus that a fibrous cord forms within the constricting band.

[1] Luigi Porta. Delle alterazioni patologiche delle arterie per la legatura e la torsione. Milano, 1845, pp. 350, 351, plate V, figs. 3 and 5.

ON THE CORRECTION OF OPTICAL SURFACES

By A. A. Michelson

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In a recent number of the *Philosophical Magazine*, an interesting method for correcting optical surfaces by means of the interferometer, was developed by Mr. Twyman. While nothing in the paper indicates that the method is limited to relatively small surfaces, it would appear that such an application to mirrors and lenses of the size of modern astronomical telescopes can hardly be contemplated as this would involve interferometers of at least equal dimensions.

It was hoped that a modification of Mr. Twyman's method, with an interferometer of usual size, could nevertheless be employed for large lenses or mirrors.